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FUNGUS DISEASES OF SUGAR-CANE IN BENGAL.

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THE following notes are intended to serve as a preliminary account of the principal fungus diseases which affect sugar-cane in Bengal. In addition to those which I have personally seen causing damage in the course of several tours which I have made while engaged in studying the subject, I have included one or two others. These were reported to me from Bengal and specimens were sent for examination, but I have not had an opportunity of seeing them on the spot. Other diseases exist in various parts of India which have not been found in Bengal. It is practically certain, however, that some of these occur there; and further search is sure to bring them and perhaps additional ones to light.

In most cases the cause and characters of the disease are dealt with briefly. In one, however, that usually known by the somewhat unfortunate name of "red smut," fuller details are given, as it is unquestionably the most serious fungus enemy with which cane growers have to contend.

As in the case of most other diseases of cultivated crops in India, the question of treatment cannot yet be adequately considered owing to the absence of experimental study carried on over a number of years. Such experimental study has not been possible in the present case except in isolated instances, owing to the lack of an experimental station and garden. This deficiency has been recently made good by the establishment of the Agricultural Institute at Pusa. Though it is true beyond question that the lines which treatment should

follow must be determined first of all in the laboratory, yet their practical application can only be tested in the field. Certain recommendations can, however, be given even at this stage; but it appears probable that the chief means of combating these blights lies rather in the direction of choosing those varieties of cane which are naturally less liable to be attacked, or which can be made so either by selection or hybridization, than in any direct measures intended to destroy the parasite.

STEM DISEASES.

Red Rot (Red Smut).

Colletotrichum falcatum Went.

This disease was reported in a severe form on a large sugar estate in Champaran in Bengal in 1902. It was again seen by me in the same locality in 1903, and also in the vicinity of Mozufferpore and in Saran attacking other canes. Since then, with the recent rapid extension of sugar-cane cultivation in Behar, it has appeared in many places.

The history of the usual outbreak is somewhat as follows. A concrete example studied in 1902 is selected as being typical of the rest. In this case, about the beginning of August several fields separated from one another by distances of about half a mile showed obvious signs of disease. The diseased fields had all been planted for the first time with a yellow cane of the Bourbon type, the seed canes for which had all been obtained from the one locality. Other varieties of cane growing in close proximity to the diseased ones were not attacked. The following season (1903) this localization of the disease to one only of the several varieties of cane growing on the estate was still more marked. Wherever the yellow Bourbon of the diseased stock was planted, disease broke out, while none of the other varieties was affected. Even in neighbouring villages to which the seed had been distributed, and where cane had not previously been grown, disease appeared.

PLATE II.

FIG. 2.—PART OF A CANE FIELD AFFECTED BY RED-ROT.

as that described by Mr. Barber in Madras. The Behar and Madras outbreaks, however, differ in several respects, and I have often failed to find these blotches even in canes well advanced in the disease.

The reddening of the internal tissues extends right down into the stool. When only one cane of a stool has commenced to wither, the other full-grown ones, connected with it at the base, often show signs of attack. On cutting them open they show red streaks, even though outwardly they appear quite healthy. To gain a full idea of the destruction it is therefore necessary to dig up the stool and examine all its shoots in their underground parts. In this way, too, it can be ascertained that young shoots are not attacked.

In almost every case in the particular outbreak here described (96% of stools in one instance where a large number was examined) the underground parts were found to be bored more or less freely by a boring insect, probably *Polyocha saccharella* Dudgn. At first sight this borer would appear to be the cause of the withering and death of the canes. Even though, as we shall see, there is another parasite present, the damage done by the insect is so patent that it was natural to attribute a great part in the disease to it. But further examination proves that the borer alone cannot cause anything like the general destruction which is here the case.

At a later stage the red colour is found extending up the inside towards the top of the cane. The latter gets very light and loses much of its juice. The colour then changes to an earthy hue or even blackish. An old case shows the cane fallen over, completely withered, very light, and the inside consisting of dried crumbling pith of a deep brown colour. Such a cane contains practically no juice.

The discoloured internodes at the base of a diseased cane are filled with the mycelium of a fungus visible only under the microscope. It can be found from the very first by taking a thin section through the reddened pith. By this

means it is possible to determine with certainty that it appears first of all below the surface of the soil. In the early stages of attack it is common to find canes whose lowest, buried, internode contains the fungus, while the rest of the cane is free from it. No other interpretation can attach to this than that infection takes place from below either from the soil or from the parent set. I have so frequently found stools, picked out because one cane appeared to droop, in which the fungus was present in one or more of the apparrently healthy canes in their lowest internode only, that I have no doubt of the correctness of this interpretation.

How far there is any connection between the presence of a boring insect and a fungus in diseased canes cannot yet be determined with certainty. Frequently there is no trace of the latter in the outwardly healthy stools of other varieties examined, though these may be badly bored. In the course of the investigation a large number of stools have been examined both of the diseased yellow Bourbon above mentioned and of other diseased canes and also of *Pounda*, *Shamsara*, *Kajli*, *Boorli* and other varieties not suffering from the disease. Borers were found in all these canes in varying proportions attacking the underground parts. The insect appeared to be almost always that referred to above as being probably *Polyocha saccharella* Dudgn.

Only these two parasites have been found. Since the borer is often present on healthy as well as diseased canes, it cannot be held directly responsible for their death. Moreover there is something totally unlike the action of a borer in this wholesale and rather mysterious dying out as the cane approaches maturity. Suspicion therefore falls on the fungus, and when it is found that this is a well-known and virulent cane-parasite, suspicion becomes for all practical purposes certainty.

Whether the fungus enters through the borers' holes or precedes the latter is uncertain. There is some evidence, as will be seen presently, that it is to be found from the very germination of the sets and therefore precedes the borer. If

the borers' holes usually give entrance to spores or filaments of the fungus, it is not easy to understand why the latter was so rare in other bored canes growing side by side with the Bourbon. A view put forward on more than one occasion, that the borer is attracted by the results of the acid fermentation which appears to be set up by this fungus, must be borne in mind when considering this question.

Though the presence of the fungus from an early age, perhaps even from the set, is probable, no bad effects result until the cane approaches maturity. It may be that active growth does not occur until the cane is rich in sugar. That the parasite is closely concerned with the sugar contents of the cane is apparent from the following analyses. These show that even at an early stage in the attack the sugar is greatly diminished in diseased canes. The drying up of the cane is not the only, nor even the most serious, consequence of the action of the parasite. Were it not for this impoverishing effect, it might be possible in many cases to crush the cane as soon as the first signs of drooping were noticed.

Samples of diseased and healthy canes of yellow Bourbon were taken for analysis as follows :—(A) Twelve well-grown canes were selected which showed the first signs of disease by drooping of the leaves and by the presence of red markings in the lower internodes on cutting ; (B) Twelve others from the same plot and of about the same size but showing no signs of disease. The cane was some months from full maturity which explains the low figures of the healthy cane—

	Degrees Brix.	Sucrose.	Quotient of purity.	Available Sugar in Juice.
(A) Canes showing disease in its early stages ...	11·3	8·0	70·8	4·7
(B) Healthy canes from the same plot ...	13·9	11·2	80·5	8·5

This shows a diminution of 45 per cent. in the available sugar of diseased as compared with healthy canes.

In 1905 careful analyses were made by an assistant to the Agricultural Chemist to the Government of India of two samples of ripe *Kajli* cane, similar outwardly but with the reddening of the pith indicative of the presence of *Colletotrichum* in one sample. The results were as follows:—

	% cane sugar per 100 c. c.	% glucose per 100 c. c.	Density.	Temp. °C.	% juice to cane.
A, unreddened cane ...	19·09	·509	1086	18°	55·58
B, reddened cane ...	13·70	2·04	1070	18°	55·58

The diminution in cane sugar and increase in glucose which result from the disease are well marked.

To determine the cause of the increased glucose present in diseased cane, experiments were carried out in conjunction with Dr. J. W. Leather, Imperial Agricultural Chemist. Flasks were filled with cane juice of known composition and inoculated with pure cultures of *Colletotrichum falcatum*. After standing for some days the juice was again analysed, with the following results.

	% cane sugar per 100 c. c.	% glucose per 100 c. c.
Juice at commencement of experiment	21·90	·70
Juice after action of *Colletotrichum falcatum*, filtered free from fungus	20·05	2·20

From this it appears that the actual consumption of sugar by the fungus is slight compared to its inverting action.

Attempts to produce inversion by the juice in which *Colletotrichum* had been grown for a week, filtered through porcelain into sterile flasks, failed either because the ferment is non-diffusible from the interior of the fungus cells or because it is formed in such small quantities as to be entirely taken up in passing through the filter, as is known to occur in many ferments.[1]

[1] See Duclaux, Traité de Microbiologie, Vol. II.

From the above we can understand how it is that the presence of the fungus in a portion only of the cane is sufficient to impoverish the whole and render it unfit for sugar making.

In the early stages of the disease there are usually no other indications of the presence of a parasite than those given above. It is not until later on that, as the cane dries, cavities appear in the pith which rapidly become filled with the dense cobweb-like mycelium, while at the same time spore-bearing organs are formed outside at the nodes and in sunken-in areas in the internodes (Fig. 1, *b*). However, it is possible by the following method to obtain spores which allow the fungus to be identified, even at a very early period. A cane whose outer leaves are withering is cut down level with the ground. The lower internode or two of the cut piece will now generally be found to show red streaks or patches. A knife with a long blade is heated to redness, and a small piece is cut out of the reddened part by means of six incisions, heating the blade before each cut. The resulting slab is rapidly transferred to a sterile test-tube containing some water or damp cotton-wool. In 24 hours a copious growth of the fungus is visible from the vicinity of the red patches, and in two days spores, which permit it to be identified as *Colletotrichum falcatum* Went, are produced.

In many examinations of the sort described, I have always found this fungus and usually only this, and, if the operation be rapidly performed, a pure culture in the strict scientific sense of the term can be relied on in nine cases out of ten.

The fungus *Colletotrichum falcatum* was first described by Dr. Went in Java[1] as the active cause of the disease to which he gave the name of "Red Smut." As "Smut" however is generally used with reference to a totally different class of diseases, of which there is an example on the sugar-cane itself, it must be confessed that the name was not a happy one. I have used

[1] Went, F. A. "Het rood snot," Mededeelingen van het Proefstation "West Java," 1893.

the term "red-rot" in describing it, since the most distinctive feature is the red-rot of the internal tissues.

Its life-history was carefully followed by Went, who also succeeded in producing the disease by infecting healthy canes with pure cultures of the fungus. It now occupies, with the disease of sets caused by *Thielaviopsis ethaceticus*, and the mysterious affection known as "Sereh," an unenviable position at the head of the diseases of sugar-cane in Java.

The fungus has since been reported from the West Indies,[1] Queensland,[2] Bengal[3] and Madras.[4] Howard in the West Indies, repeating Went's inoculating experiments, found that the characteristic symptoms of the dreaded "Rind disease" of that country were produced by it.

The following is an account of the life-history of the fungus as it occurs in nature and in artificial culture.

In the living cane the microscope reveals it as an irregular network of fine colourless filaments ramifying in and through the cells of the pith. These filaments are so like those of many other fungi that their presence alone tells nothing of the nature of the parasite. One peculiarity, however, they possess, that within them can be seen numerous little bright globules which are probably droplets of oil. Spores are not ordinarily produced until the cane dries up, and their formation and the further details of the life-history can best be studied in artificial culture.

The spores of *Colletotrichum* are produced within two days in cultures obtained as described above, by cutting out a part of the diseased tissue under aseptic conditions, or generally in any culture on living cane material. It is a simple matter to obtain sterile slabs from the interior of living healthy canes by the same method. These should be incubated

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1 Massee, G. "Root Disease of Sugar-cane," Kew Bulletin, No. 48, 1893.

2 Tryon, H. "Some Obstacles to Successful Sugar-cane Cultivation," Queensland Agricultural Journal, Vol. IX., p. 85, 1901.

3 Gage, A. T. "Diseases of Sugar-cane in Bengal," Agricultural Ledger, No. 5, 1901.

4 Barber, C. A. "Sugar-cane in the Godavery and Ganjam Districts," Bulletins of the Madras Department of Agriculture, Vol II., Bulletin 43.

for a couple of days to test the absence of other organisms. On dead, boiled cane-slabs, boiled cane-extract, gelatine, dextrose-gelatine, agar-agar and other nutrient substances which I have tried when studying the growth of the fungus, spores are often not produced until later (8—10 days on sterilized cane-slabs). On the whole these media are less suitable for study than the unboiled cane-slabs.

A culture examined on the second day shows the following appearance. The filaments of the fungus extend in a whitish fluffy mass from the surface of the slab. Spores are first seen produced singly on short lateral branches. They arise at the tip of the branch and as soon as completely formed fall off (Fig. 3). On the second to the fourth day definite spore-producing areas known as "stromata" are formed. Each consists of a densely-woven felt of filaments with short branches, matted together until the filamentous character of the fungus is almost lost. The stromata are visible to the naked eye as tiny black dots by the third or fourth day. Their component filaments are soon differentiated into two kinds at the surface of the stroma. The majority are short, crowded and turned more or less at right-angles to the surface; from their tips spores are budded off in large numbers so as to cover the surface with a dense layer. Others, fewer in number, grow out into long dark hairs sometimes scattered but more usually forming a sort of fringe round the edge of the stroma (Fig. 4).

The spores are more or less sickle-shaped, undivided and measure from 20 to 30 thousandths of a millimetre in length by 5 to 7 in breadth. They contain a large refractive dot in the centre (Fig. 6). The hairs are dark greenish-brown with several septa, and are about four to six times as long as the spores.

At an early period a second sort of spore is formed in the cultures. This is what is known as a "chlamydospore" ("gemma" of Went). It is formed out of an ordinary filament of the fungus, either at the tip or in its length. A

portion of the filament is cut off by septa and becomes thick-walled and dark in colour (Fig 5). The chlamydospores are better adapted to stand unfavourable conditions of preservation than the ordinary spores; though the precise part they play in carrying on the disease is not known, yet their presence in large numbers has probably much significance. The quantities that are found in some cases in the interior of diseased canes may be a means by which disease is disseminated when the latter are left to rot on the ground.

On germination the spores sometimes divide into two cells by a transverse wall (Fig. 7*a*). They germinate by giving out one or a couple of filaments from near the ends. These filaments may develop directly into a new plant, or may give rise at the tips to secondary chlamydospores resembling those just described (Fig. 7). After a period of rest these secondary spores themselves germinate. A case where the chlamydospore thus formed germinated exceptionally quickly while still attached to the primary spore is shown in Fig. 8.

As mentioned above there is usually no outward sign of the fungus till late in the disease. When the cane dries up natural spore-formation occurs. Stromata and spores are developed on the surface of the rind from small masses of filaments that have forced their way through it. These are inconspicuous and readily escape observation. They are often formed just above or below the nodes and, when in quantity, may be seen as minute black bodies with a more or less hairy appearance (Fig. 1, *b*). In withered canes I have also found the stromata crowded together in sunken areas sometimes several inches in length on the surface of the internode. Mr. Barber lays stress on a copious production of spores within the cavities of diseased canes which he has several times noticed. I have more commonly observed a very free growth of filaments forming a dense web in the cavities. This I have ascertained by culture to be almost invariably a mixed growth of *Colletotrichum* with chlamydospores, but few ordinary spores, and a second quite distinct fungus. The

latter is a species of *Verticillium* or allied fungus with very small spores.

Canes advanced in the disease often show the thin-walled colourless filaments replaced by thick-walled brittle dark-coloured ones on which chlamydospores are found. A similar development often occurs in artificial culture.

As the spore-production is so slight as to lead one to doubt that it can play any considerable part in communicating the disease, some experiments were made to test the vitality of the spores. Spores from a vigorous culture buried in the soil at a depth of 3 inches were found to be all dead or germinated after 8 weeks, and even the mycelium which had been strongly developed both as regards colourless and dark filaments was all killed. On the other hand cultures placed freely exposed on the surface of the ground in dry weather survived and germinated freely after the same period. The moisture of the soil had probably caused all the vigorous spores to germinate in the first and they had perished for lack of suitable nutriment. I have found spores that had been kept for over five months in the laboratory germinate as freely as in the beginning.

A further test of the vitality of the thin-walled ordinary spores was made by determining their resistance to the toxic action of Bordeaux mixture. Vigorous cultures were treated by immersion in Bordeaux mixture of a strength of 6 lb. copper sulphate and 4 lb. lime to 50 gallons of water for periods varying from 5 minutes upwards. It was found that a treatment of two hours was sufficient to destroy completely the power of germination.

Besides the form of "red-rot" described above, there appear to be several other ways in which *Colletotrichum falcatum* can attack sugar-cane. One of these differs chiefly in the position of the first attack. Cases are often seen where one or more nodes towards the middle of the cane are attacked. In all such cases which I have seen there is a greater shrivelling-up of the affected internodes than when it begins at the bottom. It appears to be this type which is

prevalent in Madras.[1] Red blotches with a white centre are also said to be found invariably in diseased canes on cutting open, in this locality, whereas I have often failed to find them. Spore-production also appears to be somewhat more frequent. However, unless the disease is watched step by step from its commencement, it is easy to overlook its origin from below. Shrivelling is usually most marked in the middle of the cane even when the fungus has arisen from the stool, and spore-production is more frequent here and not, as might be expected, at the lower nodes.

Another form is sometimes found on the true roots below ground. Massee[2] has described this form, and I have found stromata at the base of the true roots which appeared disorganised from the action of the fungus.

A third occurs on the leaves. Dead or fading leaves very often bear stromata and spores. Went and others have stated that this form is not parasitic but saprophytic, *i.e.*, living on dead tissues only. There are, however, certain gradations between the truly parasitic and the truly saprophytic forms. Figure 9 shows a condition which is common enough almost to merit consideration as a definite disease. The midrib over a greater or lesser extent is reddened and eventually dries up. On the dried up part numerous stromata of *Colletotrichum* appear. Whether this fungus is the same species as that causing "red-rot" can only be determined by direct experiment. A closely allied species, *Colletotrichum Lineola* Corda, is common on the leaves of *Andropogon Sorghum* (Jowar), causing a rather similar appearance at times.

In certain parts of the world where "Red-rot" is frequently found, it would appear that the chances of obtaining a pure culture of a single fungus by the method described above of cutting out a piece of cane aseptically are less than in India, for recent researches go to show that the cause of the disease,

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[1] Benson, C. "A sugar-cane pest in Madras," Madras Dept. of Agriculture, Vol. II., Bull. 36. Barber, C. A. *loc. cit.*

[2] Massee, G. *loc. cit.*

the parasitic *Colletotrichum*, is accompanied, or at least closely followed, by another fungus. This is the well-known *Trichosphæria Sacchari* Massee, long held to be the cause of the West Indian "rind disease." There is no more remarkable case in the whole history of vegetable pathology, as illustrating the extraordinary subtlety of the attack of some of the parasitic fungi, than that presented by these two species.

For years the *Trichosphæria Sacchari* was known to every planter in the West Indies and dreaded as the most terrible enemy to which his crop was exposed. Any one, indeed, who has ever seen a "rotten-cane" bearing this fungus, will understand how it was taken to be the origin of the damage. From hundreds of ruptured areas in the rind it bursts out in long black sticky filaments (Fig. 26). These break up into innumerable spores. This condition is known as the *Melanconium* stage (for, as with so many fungi, this is a polymorphic species having more than one form). The spores are called *Melanconium* spores. It was supposed that the storms of spores from such canes that swept through the Islands accounted for the constantly recurring disease. Lately however this view has been shaken by the investigations of Howard. Direct experiment with these *Melanconium* spores has shown that they do not possess the power of infecting healthy cane or only to a slight degree. Further investigation has brought to light the remarkable fact that *Colletotrichum* co-exists with the *Melanconium* within the cane. Owing to the above-mentioned slight external signs of its presence, it had hitherto been overlooked. It is true that Mr. Massee at Kew had long since given his opinion that *Colletotrichum falcatum* did produce disease in the West Indies, as to its agency he ascribed the "root-disease" there. Later on he found it so closely associated with *Trichosphæria* that he suggested they were forms of one and the same fungus. Though later work has not supported the view that the fungi are identical, it has confirmed their frequent co-existence. Howard has found that most of the specimens of "rind disease" examined by him showed both fungi. He has

gone much further than this and shown that *Colletotrichum* is the active agent in the disease, the other being only a follower, for the spores of *Colletotrichum* gave rise to the symptoms of "rind disease" when inoculated on healthy canes while those of *Melanconium* did not. Pure cultures of the two fungi were used in the experiments. It was found that in order to get the *Melanconium* spores to infect cane it was necessary to inoculate the latter first with *Colletotrichum ;* it was only in the portions already diseased from the presence of *Colletotrichum* that the *Melanconium* could gain an entrance.[1]

This work explains why it is that, though a disease has long been known in India having many of the characters of the West Indian "rind disease," yet the fungus assumed to be the cause of "rind disease" had only very rarely been found here. Indeed, I know of only three cases where the *Melanconium* spores of *Trichosphæria Sacchari* have been obtained in India, other than from imported cane : one a specimen in the Kew Herbarium from Saharanpur, and the others obtained by me in Behar and Madras respectively. Out of the hundreds of diseased canes examined by those who have studied the disease in India, it would certainly have been more frequently met with if common. The natural conclusion was, until the publication of Howard's work, that "rind disease" does not occur here. In Java the same conclusion was reached, for though a fungus was found there, apparently the same as the West Indian form, it was proved to be harmless. We are now confronted with the knowledge that the "rind disease" has been misunderstood in the West Indies and has proved to be connected with that well known in Java and India as "red smut" or "red-rot."

It is perhaps too much to conclude definitely yet that "rind disease" and "red-rot" are the same thing under different names. We do not know sufficiently what part the *Melanconium* form plays when it accompanies or follows

[1] Howard, A. "On some Diseases of the Sugar-cane in the West Indies." Anns. of Bot., Vol. XVII, 1903.

Colletotrichum falcatum. It may increase the virulence of the latter and hasten the death of the cane. In some respects the published descriptions of "rind disease" in its early stages differ from those forms of "red-rot" with which I am familiar. The external marking of the cane in the beginning is a feature not often met with in "red-rot." But the fact that *Colletotrichum* is an active parasite while *Trichosphæria* is at best a feeble one, cannot but indicate that the former is at any rate the principal factor in the West Indian rind disease.

As above mentioned it has been suggested that the two fungi are but forms of the same species. Some experiments carried out at Kew appeared to establish such a connection, but all attempts since then have failed to obtain any support for this view. I have kept *Colletotrichum falcatum* obtained in Behar, and the *Melanconium* stage of *Trichosphæria Sacchari* got both from Behar and Mauritius, in constant cultivation side by side on a variety of media for over 18 months, without producing anything but the spores proper to each form. These cultures were kept under a wide range of temperature, as the mean temperature of the Laboratory at Dehra Dun varies from about 55° in the winter to over 90° in the hot season. Temperature alone is not likely to account for the discrepancy in the results at Kew and in the tropics, for the disease is found in India from tropical to almost temperate regions. Went in Java and Howard in the West Indies have had results similar to mine.

In comparing the life-history of the more notorious *Trichosphæria Sacchari* with *Colletotrichum* one difference of great practical significance is found. The immense discharge of spores into the air so characteristic of the former is absent in the latter. As long as the cane is standing there is little risk of air-borne communication of "red-rot." This fact alone should make the disease decidedly easier to cope with. Dead and dried-up canes, however, are a distinct source of danger. From the stromata which then appear on the surface of the

rind, spores are thrown off. When decomposition sets in also and the cane breaks up, the chlamydospores and mycelial masses within are set free into the soil.

We come at once to the question therefore of how the disease is transmitted. Unfortunately this is as yet far from being fully answered. It has been observed by Went in Java and by Mr. Barber in Madras that the progress of the disease from field to field is slow under ordinary circumstances. Nothing was more remarkable in Java than the slow, steady march from estate to estate. When, however, seed from a stock that has got diseased is planted out or distributed around the result is different. In the estate in Champaran above referred to, the disease had spread for some miles in a single year. But it was noticeable that it remained confined to the produce of the seed from the diseased stock and its extension was merely due to the distribution of this particular variety of cane. The explanation must be either that this cane was itself extraordinarily liable to the disease, or that it had carried with it the germs of infection. The former view which I was at first led to accept is controverted by several points. Some of the villages to which seed was given had never before (within recent years) grown cane. They were some miles distant from neighbouring cane fields. It is not easy to see where the infection could have come from here. Besides the type of disease, in many respects a peculiar one, was everywhere the same. Were the disease air-borne, I should have expected to find internodes which showed cracks or borers' holes—and there were many—showing the disease. This has apparently been found in most other epidemics of red smut. But here, in every case where the yellow Bourbon was concerned, the red colour appeared first below, and the fungus was, in the beginning, found in the lower nodes only. It was not until a later stage that the middle became affected; and shrivelling of the cane, not found in the commencement, was then apparent.

It therefore became of importance to determine whether the fungus could be found in the sets. Fortunately for this

purpose some fields had been planted out with sets from the diseased variety a month or six weeks previous to my arrival, at a time when disease was not much in evidence. The lower nodes, at least, of the canes from which the sets were taken, might be expected to contain fungus elements within them. It was found that a number of these sets had commenced to wither and die back when the shoots were some six inches above ground. They were examined and actively growing *Colletotrichum* found in the base of the shoots, while well developed and apparently recently formed stromata with numbers of spores occurred at the nodes of the decomposing set itself. Borers and white ants were not particularly in evidence and I see no reason to doubt that death was due to *Colletotrichum*.*

The cause of the disease was thus proved to be present in the sets shortly after germination. Being found vigorously growing six inches below the surface of the soil, it was evidently not carried to them through the air but had either been present previously in the soil or was carried on the sets themselves. The shoots had been above ground too short a time to admit of growth downwards of the fungus within their tissues from a point of infection above ground. Besides, the shoots at this stage are closely covered by the first leaves, and though the fungus is sometimes found on leaves, these are always, in my experience, old or faded ones. It is, besides, generally supposed to be non-parasitic on the leaves though, as stated above, a form on the mid-rib appears to be a true parasite. But it does not, even in this form, pass back through the leaf-sheath to the stem. Hence the leaves form an efficient protection to the young shoot, and air-borne infection at this period may be left out of consideration.

The likelihood of the spores having been present in the soil before the sets were sown is not great. As mentioned already the fungus is remarkable for its scanty spore-production until the cane is dried up. At this time (the sets were

* White ants appear, from a large number of failed sets examined in various localities, to be the prevailing cause of failure to germinate of cane cuttings in the Gangetic Plain.

planted in September) hardly any dried-up cane, even in the diseased variety, was to be met with. Were irrigation resorted to, we could understand how spores could be disseminated by canes lying in the water-channels from the previous year. This means of spreading is particularly suggested by Mr. Barber in connection with the Madras outbreak. But in the localities under consideration, irrigation was not at that time practised. Besides, some of the villages near the estate whose cane was diseased had not grown any cane for some years previously. And, finally, taking into account the wholesale manner in which the Bourbon died out, while no other cane suffered, we should have to imagine a degree of predisposition to the disease on the part of the former which is beyond anything at present known. Some of the other canes, at least, should have been attacked, were the fungus generally present in the soil.

The conclusion, therefore, to which I have come provisionally, is that it is the sets themselves which carry the disease in the majority of cases. This view is supported by some other observations. A field of about three acres, which had suffered severely from disease in 1902, was planted out again at my request after the diseased crop had been removed, in equal parts with the yellow Bourbon and two Bengal canes, *Shamsara* and *Kajli*. The Bourbon cane as usual began to die out in the following September and October, while the other two showed no sign of disease. Even allowing a great degree of resistance to be possessed by these two canes, an odd one should have been attacked were the disease soil-borne. For here if anywhere the soil might be expected to be infected. But not a single cane of either of these two sorts showed "red rot" up to November 1903, when I saw it last, though by that time about a quarter of the Bourbon had withered and most of the rest was reddening at the base. Even those stools of the two Bengal canes which were bored in the parts below the surface of the soil showed no signs of fungus attack.

Another case of a similar nature was seen in Saran in 1903. Some fields which had been chosen as the best land

available were planted out with a cane obtained, I think, from Gorakhpur, when sugar-cane cultivation was started on the estate in question. It had never done well, and when I saw it the crop was evidently diseased. Examination showed that *Colletotrichum* was present. The rest of the estate was singularly free from fungus diseases except those due to leaf-fungi. The facts here pointed to the introduction of diseased cane rather than to soil-infection.

The experiments mentioned above, which go to show that the spores and mycelium buried in the soil have entirely germinated or died in 8 weeks, give another argument in the same direction, for they show that the fungus is not one of those adapted to a life in the soil.

In discussing the West Indian form of *Colletotrichum* which gave rise to the disease then known as "root disease," Mr. Massee[1] considered that it was probably conveyed by diseased sets. Unfortunately no experiments appear to have been made to test this view. Some trials to test the effect of treating the sets in such a way as to preserve them from external infection and also to destroy any spores on the surface themselves are now in progress in Behar. Their results should go far to show whether the sets contain the fungus within them or are infected from without. Until this and other experimental work is complete, it is not possible to say more than that there is a somewhat greater probability of diseased sets carrying the fungus than that it is soil-borne.

It must not be supposed, however, that we are likely ever to prove soil infection non-existent. Certain cases of it must undoubtedly occur. The fungus being a wound parasite must be capable of attacking sets if it comes into actual contact with their cut ends. This I have proved by actual experiment. It must sometimes occur that spores have been liberated in

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1. Massee, G., "Root Disease of Sugar-cane," Kew Bulletin No. 84, p. 345, 1893. This must not be confounded with the present "root disease" in the West Indies, the most serious disease in those colonies at the present moment. It is due to an entirely different fungus which has not yet been found in India.

soil which is brought into contact with the ends. Only it appears from the present evidence that this does not usually happen, and that to the use of diseased sets the epidemic outbreaks are to be traced.

Acting on this assumption the sugar-cane varieties which, some 25 in number, were introduced into Pusa in 1904, were subjected to a rigorous examination and all sets showing any indication of disease were excluded. This was repeated in 1905. As a result all the varieties, with one exception, are practically free from disease, though in several cases the cane came from previously diseased stock. The exception mentioned is a Madras cane, *Yerra*, in which, in spite of selection, disease continues to appear. The type of disease in this case is similar to that which prevails in the Godavery delta, the upper part of the cane being frequently attacked before the lower, and the infection seeming to originate rather from wounds than from the stool. It is possible, therefore, that there are two types of disease differing in their mode of origin—one, that common in Madras, where the first attack is at any part of the cane, and the other, the common Behar type, which originates in the stool. In the former, selection of sets is not sufficient to check the disease, the cane being so weakened as to be readily attacked through the rind or wounds. In the latter, above-ground infection is rare and selection of seed usually is effective. In the one case the cane is susceptible to attacks through the rind, whereas in the other it is resistant to these attacks though still capable of infection through the set. Further experiments are in progress to test this view.

Treatment.

The first and most important consideration is the selection of suitable varieties for growth in a locality where disease is prevalent. It is clear that a cane variety which has become diseased should not be used for propagation, for there is no doubt that sets from a diseased stock are liable to give a diseased crop, whether this is due to the fungus being carried

in the sets themselves or to such sets being weakened in their resistance to fungus attacks.

At the same time it does not follow that because a given variety, the seed of which has been obtained from one locality, is diseased, the same variety from another locality will also be diseased. The following is a good illustration of this. The yellow Bourbon cane above referred to, which suffered so severely, was all obtained from one place, while what was apparently exactly the same cane from the Patna district was entirely free from disease. Yet the two were growing side by side under precisely the same conditions.

There is, I think, greater safety in using native varieties than in importing from abroad. Experience has shown—explain it how we may—that new importations are particularly liable to fall a prey to disease. Where a foreign variety is introduced, it will probably be found better to grow it for some years in seed-beds with careful cultivation before planting out on a large scale.

Fields which have suffered from disease in the previous year can be immediately replanted with other varieties with safety. But to ensure this, it is necessary to select such varieties with care, choosing only those which have been healthy the previous year, and examining the sets carefully before planting. In the case of the 3-acre field mentioned above, the Bengal canes *Shamsara* and *Kajli* escaped disease entirely, though replanted immediately on land that had borne disease. I am aware that rotation is looked on as one of the great safeguards against recurring disease, and this is no doubt true as regards very many fungi. But the evidence which I have collected regarding the form of "red rot" dealt with here shows that, for it, rotation is useless if diseased seed be employed, and is unnecessary if the seed be healthy.

"Rotten canes" (*i.e.*, those which have dried up from disease) with their leaves should be collected and burnt. Though the danger from spores floating in the air is much less in "red rot" than in many other diseases, still there

must be a certain amount from this source. Canes left lying on the field continue to produce spores for some time. There is indeed nothing to be gained by leaving a cane standing once it has shown signs of drooping, for it is never likely to be worth crushing. It was found advisable in the Champaran Estate referred to, to clear the affected fields early in November, when the cane was still unripe, and to use the tops as fodder. No doubt by this means spore-production was greatly checked, for, at the time of cutting, it was excessively difficult to find spores.

I see no reason, however, to advocate the general burning of the trash in fields, except perhaps where the disease has been particularly severe. It is a practice which has not found much favour with practical planters anywhere, and leads to the loss of a valuable supply of organic matter to the soil. So long as there is no definite proof that the disease is primarily a spore-borne one, so drastic a proceeding seems uncalled for.

Ratooning should be abandoned where disease is prevalent in any variety which is affected. The ratoons from a diseased stock are, in my experience, invariably diseased.

Selection of seed is, next to selection of the variety, the most important consideration. Generally speaking its importance is understood by all cane-growers. But I met with a few instances where I was told that a set was considered fit for use as long as it was fairly juicy, even though the inside were reddened. The least trace of redness should be a danger signal. It is quite easy to get coolies on the Estates sufficiently trained to be relied on in this matter, and village cultivators would be quite as careful if they understood the danger a little better. The loss from discarded seed would sometimes be heavy but some of it could be crushed. Unfortunately, even with the greatest care, it is not possible to eliminate diseased sets entirely, for I have obtained cultures of the fungus from sets passed by a particularly careful man, and the reddening does not always show at the cut ends.

Amongst the predisposing causes to "red rot," over-irrigation and want of efficient drainage hold the first place. Great stress is placed on this in the papers of Dr. Gage and Mr. Barber already mentioned. It is a matter of common observation that low-lying, ill-drained fields suffer most. In North Behar, where I have chiefly seen the disease, water-logging is not common and irrigation, so far as I have seen, not excessive. But in Lower Bengal and Madras, excess of water around the roots of the cane appears to be almost constantly associated with disease.

Next to this is the inherent liability of some varieties to be attacked. It is unfortunate that our knowledge of the causes which predispose to fungal attack in plants are practically unknown. The fact must however be noted.

The attacks of boring insects are probably to be considered as a predisposing cause. This may be due to the fungus gaining an entrance through the wounds caused by borer-holes, as is often held. I have found nothing definitely supporting this view. It may equally be due to the weakening effect of the insect attack on the health of the cane.

Finally, it must be borne in mind that "red rot" is known practically in every country or colony where cane is grown, and that hence it is as necessary to examine imported seed for signs of the disease as any other. Indeed, unless the seed has been treated protectively against infection on the journey, it is even more so. Spores are liable to be introduced when packing, or to be carried in on the canes themselves. It is certainly desirable in every case to insist that imported seed should be fumigated, or better, have all cut ends tarred, in the country in which it is grown, immediately when cut for exportation.

SMUT.

Ustilago Sacchari Rabenhorst.

This disease is a true smut, allied to the well-known smuts of wheat, barley, maize, sorghum, etc. It is the most easily recognised of the fungus diseases of sugar-cane.

Affected plants are known by the production from the growing apex of a long whip-like dusty black shoot, often several feet in length and much curved on itself (fig. 10).

This shoot is an entirely abnormal growth, devoid of leaves, slender and flexible. It must probably be taken to represent an abnormal floral shoot. In its earlier stages it is covered by a silvery-white thin sheath which soon, however, ruptures, exposing a dense black dust consisting of the spores of the fungus.

From the upper portion of the affected cane no secondary shoots arise, but from its lower part they are fairly abundant, being all in their turn attacked and prolonged into spore-containing organs. In this way it becomes evident that the whole plant is affected.

The tissues of the cane below the abnormal shoot contain the filaments of the smut-fungus. These are found between the cells, not in them as is the case with *Colletotrichum falcatum*. Diseased canes are poor in sugar and worthless.

Spores are only produced in the whip-like shoot. They are formed at the periphery of this under the silvery sheath. The latter consists of the raised and ruptured epidermis provided with hairs and stomata, and sometimes some of the subjacent layers with a few of the vessels. The centre of the shoot consists of large, thin-walled parenchymatous cells with numerous scattered fibro-vascular bundles.

The spores are spherical, single-celled, light brown and smooth-walled. They measure some five to eight thousandths of a millimetre in diameter (fig. 11).

They are disseminated by the wind and germinate readily on falling into water or moist earth. On germination a short filament, called a promycelium, is formed, and on this are borne secondary spores termed sporidia (fig. 12*a*). The sporidia are narrow, elongated bodies which under favourable circumstances in the soil can bud out other bodies like themselves after the manner of yeast cells.

It is probable that the disease can be transmitted both through the infected sets cut from diseased plants which contain living mycelium and also through spores. In many cases it shows early, the young plants throwing out spore-bearing shoots when they are only a few feet high. These cases are probably due to infection carried by living mycelium in the set. In the case of spore-infection, however, it has been shown that the disease does not appear until the plants are approaching maturity. Artificial infections carried out in Java gave rise to diseased shoots in about a year. Most cases which I have seen have been in 9 or 10 months old plants, and these are probably to be traced to spore-infection on previously sound sets.

An outbreak which occurred at the Sibpur Experimental Farm, near Calcutta, some years ago, in November, when the canes were nearly mature, appeared to have been brought about in some other manner than by the use of infected sets. The plants belonged to a variety that had been introduced several years before and they had not shown disease until the previous year. No other cane on the farm was diseased and I could not find any smut in the cane fields for a couple of miles around. This shows that it does not necessarily follow that the sets should be cut from diseased plants in order to give rise to the disease. Manure, the feet or clothing of labourers, other plants imported from the vicinity of diseased cane fields, are all so many channels through which infection in the case of smut may travel. Where the cane itself is

imported, the danger is naturally greater. Mere proximity to a smutted plant would practically ensure the sets bearing spores on their surface. Contamination during handling is also a danger to be remembered. Experience has shown in the case of cereal smuts that the commonest mode of distribution is through the medium of spores which get to the grain during the handling at harvest time and remain to be planted out with it next season.

Experiments in treating this smut are still to be carried out. It is certain that all diseased plants should be burnt as soon as the attack is noticed. By this means and by taking care, of course, not to cut sets from diseased plants, the smut can be kept from doing much damage in most cases. Whether it is possible by pickling the sets in copper sulphate, or by some of the other methods which have proved efficacious against grain-smuts, to prevent spore-infection of sound sets, remains to be seen.

As a rule the disease does not cause much damage. Only certain varieties are attacked. These appear to be almost invariably the thin or reed-like canes, for I have never seen nor can I find any reference to the Pounda or Bourbon type being attacked, with the exception of a doubtful specimen got from Jubbulpore this year. *Khari* in Bengal, *Sanna Bile* in Bombay and *Nanal* cane in the S. Arcot district of Madras[1] are canes especially disposed to the disease. *Khari* is a variety which flowers commonly and may therefore be considered to approach the wild ancestors of the cultivated varieties more nearly than the ordinary non-flowering sorts. A case has been described in Java where the disease appeared to have spread to the cultivated cane from a wild species, *Saccharum spontaneum*, in the neighbourhood.

There are three fungi resembling one another closely in their external features which are sometimes found on shrunken

[1] Barber, C. A., "Sugar-cane in the S. Arcot District" Vol. II, Bull. No. 39, Madras Dept. of Agriculture.

and diseased cane culms. Of these one is that already mentioned as the *Melanconium* form of *Trichosphæria Sacchari*. To its agency was long ascribed the terrible "rind disease" of the West Indies. It is figured in fig. 26, from a specimen imported from Mauritius. As already pointed out, this fungus is rare in India, though there is unfortunately only too much reason to believe that the "rind disease" is with us, under the name of "red rot." This fungus is at present of no practical interest in India and will not be dealt with further.

The second is that which will be now described and which is known as *Diplodia cacaoicola*. It also occurs in the West Indies and has been chiefly studied there.

The third will be referred to below under the name of *Cytospora Sacchari* and has so far been found in India only.

Diplodia cacaoicola (*P. Henn.*).

This fungus was first described on dead branches of the Cacao tree, *Theobroma Cacao* from the German colony of the Cameruns in W. Africa. Later on a similar fungus was found attacking living cacao and sugar-cane in the West Indies, and Howard, who studied it there, decided that the two were identical. It is interesting, as an instance of the wide distribution of so many fungi, to find the same species in Bengal.

The species is one of the many which can live both as a parasite and as a saprophyte, *i.e.*, on living or dead material. As the latter, I have found it on canes that had been killed by red rot and on some that had apparently withered naturally. As a parasite its effects appear to be not unlike red rot, but it is not so common nor so virulent as the latter. It is, in fact, at present of quite minor importance. That it is at times a true parasite, however, has been proved by Howard, who succeeded in infecting healthy canes by inserting pure cultures of the fungus under the rind.

Affected canes are shrunken and generally show longitudinal wrinkles from the falling in of the rind on the diminished pith. The rind itself is raised into numbers of little elongated

blisters which are arranged in rows following each other closely in the row (Fig. 27). These blisters soon burst and in moist weather exude strings of spores from the mouths of the underlying spore cases. The resulting appearance is like that of the *Melanconium* stage of *Trichosphæria Sacchari*, but the strings of spores are neither so long nor so numerous and their colour is lighter. In dry weather the spores are not exuded in strings but remain as a blackish crust overlying the ruptured areas.

The spore cases or pycnidia are formed in dense or scanty stromata (masses of filaments matted together) arranged in lines under the rind. From these stromata brown filaments can be traced into the interior tissues, which in advanced cases are much blackened as a result. The main filaments often extend for considerable distances within the vessels, while shorter branches enter the parenchyma cells. Still finer colourless filaments extend through the tissues in every direction. The main filaments are longer and straighter than those of *Colletotrichum falcatum*; their walls are thicker and deeper in colour; and the fine web of colourless oil-bearing filaments seen in the latter is not formed by *Diplodia*.

The pycnidia are hollow receptacles formed of an outer thick layer of brown cells and an inner thin one of colourless thin walled cells. From those of the latter which bound the cavity, short stalks project into the middle of the space. Some of these bear spores on their tips, while others are sterile and are known as paraphyses (Fig. 29).

The spores fall off as soon as fully formed, and as fresh ones are constantly produced, they may eventually be forced out at the mouth of the case which opens at the surface of the rind. When first developed they are colourless and undivided, but later on they become deep brown and are divided by a wall into two cells (Fig. 30). They are oval, not constricted in the middle, and measure 20 by 10 thousands of a millimetre. They germinate rapidly while still in the colourless stage. I have sown them on sterile pieces of sugar-cane (without the rind)

and found that pycnidia were formed after about two weeks.

Though this fungus is not uncommon, I believe that it is not able to do much damage. I have never seen more than odd cases of it here and there in the fields. Generally it appears to occur as a saprophyte on already dead cane. Should it ever become a dangerous enemy—a contingency always to be borne in mind in dealing with fungi of this sort—its treatment will probably be in the direction of cutting out and burning all affected stems. As it does not occur on the leaves, this proceeding will have a much greater chance of success than in the case of "red rot," which on account of its widespread distribution as a saprophyte can scarcely ever be entirely got rid of.

In its natural habitat in Bengal on the sugar-cane the fungus must be considered a *Botryodiplodia* not a *Diplodia*. The former genus differs from the latter in having its spore cases immersed in a stroma. In the vast majority of cases a stroma is found in the present case. However, as Howard has pointed out, and as I have also found, in artificial culture the stroma may be absent. Hence as the distinction is not a constant one, I have adhered to the name already in use.

Cytospora Sacchari Butl.

I have not, so far, found this fungus actually in Bengal. As I have obtained it in Madras and in the Central Provinces, however, it is highly probable that it occurs in Bengal also, and I have thought it well to describe it here.

Its chief interest at present lies in the fact that it is liable to be mistaken for the *Melanconium* form of *Trichosphæria Sacchari*.

Fig. 31 gives a good idea of its external characters. The rind is raised in long narrow swellings which rupture at the top, laying bare black hard protuberances. These are pycnidia sunk, as in *Diplodia cacaoicola*, in a stroma or mass of dark hyphæ. The stroma in this case, however, is harder and more circumscribed, and it is formed of more slender fila-

ments. It is also not entirely buried in the tissues but the upper part projects beyond the surface as a free conical protrusion (Fig. 32). At the tip is the mouth, opening by a long neck into the basal part. This part shows on section the appearance shown in Fig. 33, a number of chambers, sometimes communicating with each other, being found.

Spores are budded off from all parts of the inner lining of the chambers, even from the neck. They are extremely minute, being smaller than any of those already described. They arise from the tips of branched slender filaments (Fig. 35), which project into the centre of the cavity and are only 3 by $1\frac{1}{2}$ thousandths of a millimetre in diameter.

The specimens which I have examined make it probable that this fungus acts as a parasite. On one stool examined the stem at one of the upper internodes was affected and the fungus was present on the leaf-sheath as well. The stool was still living but was much bored by some of the larger shoot-boring insects, and was consequently much weakened. The tissues of the still living shoot under the stromata were permeated by slender colourless filaments extending into as well as between the cells.

Further details of the life-history of the fungus cannot be given at present. Its distribution is not known nor whether it is a serious pest. It probably occurs sporadically only and is of minor importance.

The diagnosis is as follows:—

Cytospora Sacchari Butl. sp. nov. Stromatibus verruciformibus, seriatim ordinatis, subcutaneo-erumpentibus, pluriloculariibus, nigris, ostiolo elongato, singulo, rarius duobus præditis; sporulis minutissimis, cylindraceis, curvulis, utrinque obtusis, $3\frac{1}{2} \times 1\text{-}1\frac{1}{2}\mu$; basidiis ramosis, septatis, 12-18μ.

Hab. in culmis vaginisque *Sacchari officinarum*, India.

"PINE-APPLE" DISEASE.

Thielaviopsis ethaceticus Went.

One of the most serious cane diseases of Java is that caused by this fungus. It attacks chiefly planted-out sets, which are rotted by its action and consequently fail to germinate. Cut or bruised canes that are exposed to its attacks are readily infected, and hence the danger to which canes reserved for seed are exposed, while they are stored or in transit, is considerable. Through the unbroken rind of the culm infection appears rarely to occur.

The same fungus is found in the West Indies, British Guiana and Mauritius. Inoculation experiments by Massee at Kew and Howard in the West Indies prove it to be capable of attacking standing canes by entering through the epidermis of uninjured leaves and leaf-bases.

In Bengal I have met with it on three occasions only, all being on recently imported canes for seed, from Java and Mauritius. I have never found it on standing canes that have been grown in the country. Furthermore, an examination of sets in newly planted-out fields has not shown its presence. As remarked before, white ants appear to be the most frequent cause of failure of sets in the Gangetic Plain. It is therefore probable that the fungus has not so far gained any hold on cane in Bengal, and it is one of the chief diseases whose importation should be carefully watched.

Fig. 37 shows a section of a cane badly infected. The centre is hollowed out into a cavity and a dense black substance appears to have partially replaced the pith. This consists of blackened, disorganised cells and fibres of the cane itself, mingled with masses of spores of the fungus. On cutting open

such a cane before it has dried up, a pronounced odour of pine-apples is evident. From this the name "Pine-apple disease" applied to it in Java has been derived, and not from any connection with pine-apples. As a matter of fact, however, the latter as well as bananas, etc., are known to be attacked by the fungus if bruised or injured and exposed to infection.

The filaments are found ramifying in the cells of the pith which are coloured red. Two different kinds of spores are produced, and the blackening which eventually is seen in the pith is due to one of these.

The first spore-form—the macroconidia—is formed within the tissues. The spores are produced in chains extruded from the tips of short lateral filaments (Fig. 41), and are olive-green and thick-walled. I have never seen macroconidia budded off basipetally as described by Went.[1]

The second spore-form—the microconidia—is formed on special lateral branches in chains like the first, developed within the filament (which is often like a miniature cannon), and expelled through an opening at its tip (Fig. 39). The spores are formed usually at the surface, and I have found them produced in such quantity as to raise up the rind in a long crack from which a fluffy mass of spores protruded into the air (Fig. 38).

Each of these spore-forms can on germination give rise to both macro-and micro-conidia.

It has been stated that this fungus, like *Colletotrichum falcatum*, is only a form of *Trichosphæria Sacchari*. I have kept pure cultures on cane-slabs, starting from a single micro-conidium, under observation for more than a year without obtaining anything but the macro-and micro-conidia. In the opposite direction out of many dozens of cultures of *Colletotrichum falcatum* in the last two years I have never obtained macro- or micro-conidia. This is in accordance with the view now held in Java that both are independent species. In the West

[1] Went, Dr. F. A. "De Ananasziekte van het Suikerriet," Mededeelingen van het Proefsta. 'West Java," 1893.

Indies the evidence is somewhat conflicting. As both *Trichosphæria* and *Thielaviopsis* are rare fungi in Bengal the question is not at the moment of any practical importance. As mentioned below under the next disease, there is some reason to believe that the fungus belongs to the genus *Sphæronæma*.

Treatment.

Howard has shown in the West Indies that the immersion of sets in Bordeaux mixture, followed by dipping the ends in tar is an almost perfect preservative against attacks by this fungus. Though it is unnecessary to do this in Bengal, still importers of foreign seed might find it advisable to insist on its being carried out as soon as the cane is cut for shipment. The treatment is useless unless carried out very shortly after the cane is cut.

BLACK ROT.

Sphæronæma adiposum Butl.

A FUNGUS closely allied in one of its forms to the last was found by me in Behar in 1903. Its presence in the cane was marked by the production of dusky red streaks visible in the internal tissues. The exterior of the cane was unaffected. Placed under moist conditions a copious growth of an olive-green colour took place from the discoloured areas. This turned out to be a fungus forming endoconidia like *Thielaviopsis* but differing from the latter in other respects.

Figs. 47 to 54 show the development of the spore-forms. The endoconidia are extremely variable in size and shape, ranging from elongated hyaline spores resembling the microconidia of the last species, to large rounded spiny ones, of a deep brown colour. They are produced from the interior of short lateral sporiferous branches usually divided by two or three septa (Fig. 48). The whole is more or less cannon-shaped, with one elongated tubular cell at the apex from which the spores are discharged, and two or three shorter and thicker cells towards the base.

When spore-formation is about to begin the tip of the tube becomes softened and swells up into a globular protrusion (Fig. 52*a*); at the same time the portion of the protoplasm collected in this becomes cut off by a wall formed transversely in the tube just below the swollen part. The wall of the tube then ruptures near the base of the swelling and the softened remnant of the apex appears to be carried out and to become merged with the wall of the protruded spore (Fig. 52*b*). After the first spore is expelled others are forced out from the open mouth of the tube as fast as they can be produced, each

remaining attached to the one behind so as to form a chain. Sometimes all the members of a chain are alike, and this is especially the case in those first formed. Sometimes, however, they differ from one another widely in size and shape. As a rule the earlier ones are smooth and colourless, while those produced later are brown and spiny. All however remain colourless while still engaged in the tube. Even the large dark spiny ones often to be seen at the mouths of the tube first emerge as elongated soft colourless masses with a thick jelly-like wall in several layers. Within the substance of the outer layer spines or warts are developed as soon as the spore has been protruded. At the same time the inner layers harden to form the true wall of the spore. In the beginning the spines can often be made out embedded in the jelly-like outer layer and, even when fully formed, vestiges of this are often to be seen covering their tips (Fig. 51).

Macroconidia in the sense used by Went[1] were not observed. It is evident, however, from the above description and the figures that some of the endoconidia may be classed as macroconidia and some as microconidia, if these terms be used to denote relative size and presence or absence of colour, as is done by Massee[2] and Howard[3] in connection with the West Indian specimens of *Thielaviopsis*. As I have found every transition between the pale smooth spores and the dark spiny ones, produced alike from the interior of the sporiferous filament, I have preferred to use the term endoconidia for all.

Cultures of the fungus were kept under observation to determine if any other spore-form would appear. After about ten days a number of erect bristles about a quarter of an inch long were seen rising from the blackened fungus growth. On examination these were found to be the spore-cases of a fungus belonging to the genus *Sphæronæma* (Fig. 61).

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[1] Went, Dr. F. A. "De Ananasziekte van het Suikerriet," Mededeelingen van het Proefstation "West Java," 1893.

[2] Massee, G. "On *Trichosphæria Sacchari* Massee." Annals of Botany, Vol. VII, p. 128.

[3] Howard, A. "On *Trichosphæria Sacchari* Massee." Annals of Botany, Vol. XIV, p. 617.

It then became necessary to determine with exactitude if the two forms belonged to the one fungus. For this purpose several endoconidia were sown in tiny drops of water, one spore in each drop, hanging on the under surface of glass films placed face downwards on little circular glass chambers. The air inside each little chamber was kept moist by a few drops of water at the bottom, and the whole was sealed up by oil and cement so as to be air-tight. Film and chamber were sterilised and distilled water only was used. In this way what is known as a hanging-drop culture is made and the development of a single spore can be studied without any danger of error from the presence of other spores.

One such single-spore culture was kept under observation with the microscope. The spore germinated after eight hours putting out first one and then a second filament. These grew and in three days the appearance shown in Fig. 54, which represents a drawing of the culture, was produced. The filaments were divided into short segments by walls and were sparingly branched. One of the branches near the edge of the drop. (Fig 54*a*) grew downward into the air of the chamber and almost immediately divided into three branches. Each of these became a spore-producing hypha and liberated a chain of spores into the air. One of these chains composed of about seven spores was then picked up on a needle and rapidly transferred to a sterile slab of cane in a test tube. In three days a copious growth of olive mycelium, powdery from the liberation of quantities of spores, was evident, and in eleven days spore-cases or pycnidia of *Sphæronæma* appeared.

Hence the pycnidia had been produced as the results of germination of a single endoconidium and they were thus proved to be stages in the life of the one fungus. To this fungus the name of the higher spore-form, *Sphæronæma*, must be given.

The reverse attempt was now made, *i.e.*, to obtain the endoconidial form from spores got from the spore-cases of *Sphæronæma*. It was a simple matter to pick off these spores with a needle without picking up any of the endoconidia, since

the bristles stand up nearly a quarter of an inch beyond the latter and their spores are expelled into a fatty drop at the tip. A needle was dipped in this drop without touching anything else and a quantity of the spores transferred to a pure drop of water. From this a few spores were removed to hanging drops as before. It was not, however, found possible to get a single-spore culture on account of the fact that the spores are always joined together into groups by their fatty envelope. As they are much smaller than the endoconidia and are different in shape and colour, it was perfectly easy to convince oneself that a particular drop contained *Sphæronæma* spores only. These were kept under observation and two or three germinated in 24 hours. The drop was then transferred to a tube containing a sterilised cane-slab as before and in nine days both endoconidia and *Sphæronæma* bristles were produced.

The evidence was therefore complete that each form was able to give rise to the other.

The spore-cases or pycnidia of *Sphæronæma adiposum* are globular, hairy, and provided with an elongated, rigid, bristle-like neck up to $\frac{1}{4}$ inch long by 1/500 inch thick (Fig. 61). The mouth is situated at the tip of the neck. The walls of the latter are formed of rigid, dark-brown, septate filaments which often grow out to form an irregular kind of fringe around the mouth (Fig. 55). These filaments are closely applied to one another and are formed by the repeated branching of one or a few erect filaments. The branches may grow together or anastomose as is shown in Fig. 58, which represents a very early stage in the formation of a pycnidium. From them in immature cases it is often possible to see sporiferous filaments bearing endoconidia arise (Fig. 56).

Within the globular base the minute spores are formed embedded in a vacuolated or foamy substance. The latter is soluble in chloroform and is probably of a fatty nature. When ripe the spores are expelled embedded in this substance and remain in a translucent drop at the top of the long neck (Fig. 61).

Without previous treatment with chloroform it is difficult to obtain an isolated spore. When expelled they are grouped together in very irregular masses of from two up to some dozens of spores. Each spore is separated by a considerable distance from its neighbours by the interposition of layers of the fatty substance. The shape is half-moon or crescent-shape, one side convex and the other concave or plane.

Germination in water takes place by the protrusion of a clear filament from the spore. The filament soon becomes septate, and eventually branches and forms endoconidia.

Knowledge of the degree of parasitism possessed by this fungus and of the amount of damage caused by it is still incomplete. A cane inoculated from a pure culture at a wound made in one of the middle internodes, showed six internodes infected three weeks after inoculation. Hence, under favourable conditions it is a vigorous parasite. As, however, I have rarely seen it attacking standing canes, it probably, like *Thielaviopsis ethaceticus*, is not much to be feared as an enemy of the growing crop. The real danger is probably from its attacks on cane cuttings. A number of failed sets (*i.e.*, sets which had not given shoots visible above ground six weeks or two months after planting) were examined in Dehra Dun in May 1903. Many of these had evidently rotted from fungi, and the following gives the apparent causes of failure :—

Sphæronæma adiposum	61 sets.
Diplodia cacaoicola	6 ,,
Schizophyllum commune (a doubtful parasite)	5 ,,
White ants and rot from undetermined causes	89 ,,

Thielaviopsis ethaceticus was not found in a single case.

It was first thought that this species, so strikingly like *Thielaviopsis ethaceticus*, might throw some light on the relationships of the latter and particularly on the likelihood of its being a form of *Trichosphæria Sacchari*. It was found, however, that fungi of so many different families have the

peculiarity of forming endoconidia, that the character is practically worthless in classification. *Pyxidiophora asterophora* (Tul.) Lind. and species of *Thielavia* amongst the Pyrenomycetes, *Helotium* (*Pseudohelotium*) *cæspitosulum* Bres. and *Stromatinia temulenta* Prill. and Del. amongst the Discomycetes, *Sphæronæma fimbriatum* (E. & H.) Sacc. of the Sphæropsideæ and species of the genera *Sporendonema*, *Psilonia*, *Glycophila*, *Malbranchea*, *Chalara*, *Sporoschisma*, *Milowia*, *Bloxamia* and *Hymenella* of the Hyphomycetes are instances. Hence the fact that the endoconidia just described belong to the genus *Sphæronæma* is no reason why the endoconidia of *Thielaviopsis* may not belong to the genus *Trichosphæria*.

Quite recently, however, the pycnidia of a second species of *Sphæronæma* were found in the mycelium of *Thielaviopsis ethaceticus* which had attacked some cane imported from Mauritius and was rapidly destroying it. The perithecia have a shorter neck than those of *S. adiposum* and the spores, which are liberated in a fatty globule as before, are straight and much longer than the others, being 10 to 12 by 3μ. From their germination in hanging drops macro and micro-conidia were produced, but I have failed so far to get single-spore cultures of the pycnidiospores owing to their fatty capsule and the drops consisted each of a group of several spores. The species is still under study in order to obtain exact knowledge of its life-history.

The diagnosis of *Sphæronæma adiposum* is as follows: *Sphæronæma adiposum* Butl. sp. nov. Mycelio dense lanoso, atro, ex hyphis brunneis, ramosis composito; hyphis fertilis simplicibus, septatis, endoconidiis gerentibus; endoconidiis polymorphis, cylindraceis, pyriformis vel globosis, aliis hyalinis vel brunneis, levibus, aliis fuscis verrucosis, $9-25 \times 4.5-18\mu$; peritheciis globosis, pilosis, atris, in collum erectum, rigidum, $2-6$ mm. $\times 50\mu$, productis, ore subfimbriatis; sporidiis hyalinis, continuis, crasse lunulatis, utrinque acutis $6.5 \times 3.5\mu$, muco adiposo obvolutis.

Hab. in culmis *Sacchari officinarum*, India.

LEAF DISEASES.

BROWN LEAF-SPOT.

Cercospora longipes Butl.

Though this disease is not so striking in its effects as those described before, yet I believe that it is responsible for heavy loss in the yield of sugar where it is prevalent.

Over a large part of the province it is much the commonest cane disease. It is to be seen in almost every field in North and South Behar, except where canes of the *Pounda* type are grown. Like smut it occurs chiefly in the thin canes, but it attacks almost, if not quite, every variety of these, and is sometimes found on *Pounda* canes as well.

The disease is, like several other of the leaf diseases of the sugar-cane, confined to the leaf blade and is not found on the sheath. It appears when the leaves are not yet full grown and continues to show itself with increasing vigour till they fade.

The first appearance is characterised by the outbreak of narrow, oval spots about $\frac{1}{8}$ inch in length and of a reddish colour, visible on both surfaces of the leaf (Fig. 13). These increase in size and a brown centre becomes early evident. At the same time the tissues around the spot become discoloured and a well-marked yellow areola may be formed.

At this stage the spot is tricolour, brown, red and yellow zones being formed concentrically (Fig. 14). As it widens, however, the brown portion increases at the expense of the others and the centre dries up and loses its colour (Fig. 15). The spot now consists of a broad oval deep-brown ring with a straw-coloured centre where the leaf has dried up. These rings may reach a length of half an inch, but are usually about a quarter to a third of an inch in length by an eighth

or more in breadth. They may run together in groups (Fig. 14*a*). Even after the leaf has fallen they remain with the brown colour unaltered.

The variegated appearance of fields attacked by this spot disease must be familiar to everyone who has to do with cane in these provinces, and indeed in a great part of Northern India.

At the centre of the spot the thickness of the leaf is diminished. Here fungus filaments may be seen with the aid of the microscope, ramifying on the under surface external to the leaf epidermis. These are more rarely visible on the upper surface. The cells of the epidermis are corroded and the leaf mesophyll between the vascular bundles much discoloured. This browning of the cells is produced although the filaments do not penetrate within them. It may be due to the action of a protoplasm-destroying ferment capable of passing across the cell walls as in the case of Sclerotinia. It is certain that the cells are early killed and their contents collected in a brown mass in the centre. Those cells which do not contain living protoplasm, as the vessels and fibres, and also the thick-walled sclerenchyma of the leaf, are not affected. At a later stage, rather large, brown hyphæ force their way between the broken down cells to the interior of the leaf, and narrow cracks containing fungus are sometimes visible as a result of this.

Spores are formed soon after the brown centre makes its appearance in the spot. They are borne chiefly on the under surface, rarely above. Numerous clusters of long brown filaments rise at right angles to the surface from the centre of the spot (Fig. 19), and can be seen with a lens forming a minute, elongated, dark cushion there (Figs. 14-17). The filaments are unbranched and septate and bear elongated spores at or near the apex (Fig. 19). These fall easily and no doubt infect each new leaf as it opens.

The spores of *Cercospora longipes* are elongated, thickened below and produced above into a long tapering point. They are divided into several cells by four to six septa.

At a later stage a second spore-producing organ is found on the spots. After the centre has dried up, little sharp, black dots, arranged in rows, appear. They seem to be formed from the same filaments as the earlier form, and are found on either surface but chiefly beneath, always occupying the dried up portion only (Fig. 18). These black dots are spore-cases or pycnidia and within them spores are probably produced.

The pycnidia ripen very slowly. I have never found spores in them, even though a very large number has been examined. They are entirely closed (Fig. 20), and must set free the contained spores on decaying only and not through a mouth as in many other fungi. Hence this is essentially a persistent form of fruit, and probably serves to carry over the germs from season to season.

There is no direct evidence as yet to prove that these two forms belong to one and the same fungus. There is only the fact constantly observed of their regular succession in the same spot. The spot as it first appears is beyond doubt caused by the first described fungus (*Cercospora*). But in the event of it being eventually shown that the two forms are directly connected, the name *Cercospora* must give way to that of the second form, for in accordance with the rules of nomenclature the name of the higher spore-form supersedes that of the lower when both belong to the one organism.

Several other leaf spotting fungi belonging to the genus *Cercospora* are known to occur on the sugar-cane, but none of them that have been described so far correspond to the above. The following are the chief known:—

(1.) The "Eye-spot" of Java canes, produced by *Cercospora Sacchari* Br. d. H. This fungus has spores with equal rounded ends and the spots develop chiefly on the upper surface of the leaf. The filaments penetrate the leaf-tissues.

(2.) The "Red-spot" disease of the leaf-sheath, due to *Cercospora vaginæ* Kr. This has been found in Java, India and the West Indies, but is apparently not common in Northern India. The spores are shorter than in *Cercospora longipes*, with

fewer septa and less regular structure, and the spots are large and red and are situated on the leaf-sheaths only.

(3.) The red leaf-spot of Java due to *Cercospora Köpkëi* Kr. In this the spots are irregularly round and not sharply defined, causing by their running together large irregular blood-red splashes on the leaves. The spores are smaller and with fewer septa than in "brown-spot," and the ends are more or less equally rounded.

(4.) The "Black-spot" of Java due to *Cercospora acerosum*, D. & H. This fungus attacks the margin of the leaf base where it joins the sheath, forming black areas which extend as far as the midrib. The spores differ in size and shape from those of "brown-spot," and are borne on both surfaces of the leaf.

None of these leaf spots have been found prevalent in Bengal, and if they occur they are not nearly so widespread as the brown leaf-spot.

Direct treatment of this disease is scarcely to be thought of. Spraying with Bordeaux mixture or some similar fluid in the thorough manner which would be necessary here, would be difficult and expensive. That it is possible to check these fungi in this way has been experimentally demonstrated in Java with the allied fungus *Cercospora Sacchari*.

In connection with the latter fungus it has been mentioned in Java that "cane tired" land is much more liable to bear diseased crops, and rotation or heavy cattle manuring is recommended.

The following is the diagnosis of the fungus:—

Cercospora longipes Butl. sp. nov. Maculis elongatis, amphigenis, sæpe confluentibus, primo sanguineis, arescendo stramineis, brunneo-cinctis; hyphis in cæspitulos gregarios collectis, plerumque hypophyllis, flexuosis, brunneis, sursum geniculatis vel denticulatis, 100-200 × 4μ; conidiis obclavatis, sursum attenuatis, rectis vel curvulis, 4-6 septatis, 40-80 × 5μ, hyalinis.

Hab. in foliis *Sacchari officinarum*, India.

RING-SPOT.

Leptosphæria Sacchari Br. d. H.

This disease resembles the last in several respects. Like it the chief symptom is the discoloration of the leaf by red or brown rings with a dried-up straw-coloured centre. These are found scattered over the whole or a part of the leaf blade. A closer examination enables the two diseases to be distinguished from each other, and they are caused by quite different fungi.

The "Ring-spot" disease begins by the appearance of small, discoloured, generally purple, spots on the surface of the leaf. These grow, drying up in the centre as they expand at the margins. The ring consists of a purple or brownish band of varying depth, outside which there is sometimes a yellow areola losing itself in the green substance of the leaf. The latter is, however, never as marked as in "brown-spot" disease and is often absent (Fig. 16).

The spots are irregularly elongated (rarely regularly oval as in the rings of the last disease), and become eventually quite large. They run into one another frequently. Outside them the leaf eventually dries up, so that a feature of the disease is the premature withering of the leaf.

Microscopically it is found that the tissues at the spots are permeated with fine colourless filaments of a fungus which also spreads on the surface and gives rise there to peculiarly shaped spores (Fig. 23). Van Breda de Haan has succeeded in infecting healthy leaves with these spores.

The filaments are found over the whole surface, but chiefly at the margins of the spots, and communicate with those in the interior of the leaf. Unlike the last fungus they

enter directly into the cells. The contents of the latter are then killed and remain collected in a brown mass in the centre. As a rule the vascular bundles are not directly attacked.

The spores are formed chiefly on the under surface of the leaf on unbranched filaments. They consist of one large central cell with unequal sides, and of one or two smaller cells at the ends, the whole forming an obtuse-angled body (Fig. 23). They germinate in water by putting out a filament from each end, which can then grow into the substance of the leaf and infect it. They measure about 20 by 9 thousandths of a millimetre.

At a later stage a second spore-form appears, chiefly within the rings, but also, to some extent, outside them (Fig. 22). Innumerable black dots become visible arranged in rows between the finer nerves of the leaf. These are the spore cases or perithecia, which are buried in the substance of the leaf and open by a fine mouth at the surface. They are visible only on the upper surface of the leaf; in this respect forming a striking contrast with the spore cases found in "brown-spot" disease. Their arrangement in lines at a regular distance from one another appears to be due to the fact that they are formed in the air chambers beneath the stomata.

In these perithecia spores are formed, arranged in little sacks or "asci" (Fig. 24), each containing eight spores. The latter are elongated, usually divided into four cells, of which the two in the middle are thicker than the others. They measure about 20 by 5 thousandths of a millimetre (Fig. 25). Between the asci are sterile hairs or paraphyses.

Direct proof is wanting in this case, as in the last, that the two spore-forms belong to the same fungus. Here, as before, it appears to be the first or more simple spore-form which is directly concerned in the attack, the second being a "resting" form. Its position buried in the leaf-substance is admirably adapted for this.

The damage done by this disease is slight. I have seen a few fields of cane of the *Pounda* type severely

attacked in Champaran, Behar. In Dehra Dun it is fairly common, and I have received it from Madras. It occurs also in Singapore, Java and Borneo.

Treatment is not likely to be required as a general rule, but burning all diseased leaves might be effective in checking extension.

"SOOTY MOULD."

Capnodium sp.

Vern. "LAHI."

IT is not uncommon to find leaves or even whole plants of sugar-cane turned black by the deposit of a superficial black mould. Such plants are always found to be infested by mealy-bugs (usually a species of *Aleurodes*).[1] The mould is entirely superficial and can readily be separated in dry flakes from the leaf. Under it the leaf substance is naturally bleached, for the dense black deposit cuts off light from access to the cells which bear the green colouring matter—chlorophyll—of the leaf. Hence though the fungus is entirely superficial and not a parasite, its presence is harmful to the plant.

The mould develops in a sugary excretion known as honey-dew produced in considerable quantities by the insects. In severe cases this drips from leaf to leaf and even on to grass or weeds under the cane. Spores of the fungus are very widely distributed and are deposited from the air in the honey-dew. They germinate and grow very vigorously in this and soon cover all the infested parts, and wherever the honey-dew has fallen, with their characteristic black crust. Allied fungi are often seen on mango, peepul and other trees, and on tea and coffee plants in India, and are common on fruit trees, particularly oranges and lemons, elsewhere, being often known as "sooty moulds." In all these cases it is quite clear that the insects always found with the fungus are the real cause of disease.

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[1] *Aleurodes barodensis* Mask. Determined by Mr. H. Maxwell-Lefroy, Imperial Entomologist.

In Saran the disease is locally known as "Lahi" and is considered in some places to be the worst disease of sugar-cane. It is probable that the part played in it by insects is not understood.

Under the microscope the crust on the leaves is found to be composed of branching, septate, brown filaments which have a great tendency to round off into two-celled, oval articulations. Attached by short stalks to some of the filaments are blackish masses of cells composed of from two to many, joined together to form a more or less cubical mass. This form is known as *Coniothecium* (Fig. 63). On the filaments also are found, sometimes in great quantity, a spore-form known as *Triposporium*, composed of several cells arranged along four radii and tapering towards their free extremities (Fig. 64).

At a later period in its life the fungus produces numerous spore-cases or pycnidia, within which quantities of minute 1-celled spores are developed, to be afterwards discharged through an opening at the tip. The pycnidia are extremely variable in size and shape, but agree in being composed of deeply coloured, septate filaments and in opening at the top by a fringed mouth (Fig. 66). The oval cells formed from the filaments, the masses of cells of the form *Coniothecium*, the *Triposporium* and the pycnidia spores can all germinate under suitable conditions, so it is evident that the fungus possesses extremely vigorous reproductive powers. It is possible that there are even other forms belonging to it, for spores produced in chains on the top of erect filaments as in the genus *Cladosporium* are common in the crust, and a perfect fruiting form with groups of eight spores formed in little sacks or asci, as in the other members of the genus *Capnodium*, not improbably remains to be discovered.[1]

[1] In the absence of this perfect fruiting form, the fungus cannot properly be named. I have contented myself therefore with indicating its principal characters. It certainly differs from the sooty moulds of mango, peepul, tea, coffee, etc., which I have hitherto seen. Its chief botanical characters are as follows: Mycelium crustaceous, broadly effused, black; hyphæ brown, septate, branched, breaking up into oval, 1 to many, mostly 2-celled, articulations, $12 \times 6\mu$, here and there bearing deep brown masses of cells (*Coniothecium* form). *Triposporium* spores 3-5 radiate, radii mostly 4 septate, $20\text{-}33 \times 8\mu$; pycnidia small, slender, very variable.

Treatment should be confined to getting rid of the insects. The fungus cannot flourish in the absence of "honey-dew." Besides, though the black crust is so prominent as to lead one to suppose that its presence must be the cause of the canes languishing, it is only so indirectly and to a comparatively slight degree. The insects on the other hand are direct and dangerous parasites.

EXPLANATION OF THE FIGURES.

Figs. 1 and 2 have been drawn by Mr. Chhotalal D. Shah, Figs. 9, 10, 13, 14, 15, 16, 22, 26, 27, 31, 37, 59, 60 and 61 by Mr. H. Hormusji Deboo, the remainder by E. J. B. The great majority of the microscopic drawings were made by the aid of the *Camera lucida* of Abbe.

Fig. 1. *a*. Section of a cane showing discoloration due to "red rot." Natural size. *b*. Node of ditto, showing the stromata at the eyes above the node and in the waxy layer below.

Fig. 2. Photograph of a patch of diseased cane at an advanced stage.

Fig. 3. Stages in the formation of the spores of *Colletotrichum falcatum* in artificial culture × 500.

Fig. 4. Portion of a stroma and spores × 260.

Fig. 5. Three chlamydospores × 500.

Fig. 6. Spores of *Colletotrichum falcatum* shortly after formation × 500.

Fig. 7. Spores of *Colletotrichum falcatum* germinating with the formation of secondary spores resembling chlamydospores. *a*. two bicellular spores × 500.

Fig. 8. Secondary spore which has germinated while still attached to the primary spore × 500.

Fig. 9. Mid rib of sugar-cane leaf attacked by *Colletotrichum falcatum*. Natural size.

Fig. 10. *Ustilago Sacchari* on sugar-cane. Half natural size.

Fig. 11. Three spores of *Ustilago Sacchari* × 500.

Fig. 12. Germinating spores of *Ustilago Sacchari*. *a*. promycelium with sporidium. *b*. two sporidia. *c*. germination by slender filaments instead of sporidia × 500.

Fig. 13. "Brown leaf-spot," early stage. Under surface of leaf, natural size.

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simple or branched, cylindrical, often showing irregular enlargements, base little or not enlarged, apex enlarged, mouth fimbriated, sporidia hyaline, unicellular, often collected in mucus at the mouth, 4½-5 × 2-3μ.

Fig. 14. "Brown leaf-spot," tricolour stage. Brown, red and yellow rings surround the centre, which is beginning to dry up. Elongated cushions formed by the filaments of *Cercospora longipes* are visible in the centre of several spots. Under surface of leaf, natural size.

Fig. 15. "Brown leaf-spot," late stage. The leaf withered, but the deep brown rings are still distinct. In the centre of the spots can be seen the lines of dot-like perithecia of the second spore-form. Under surface of leaf, natural size.

Fig. 16. "Ring spot" disease. Under surface of leaf, natural size.

Fig. 17. A spot with cushion of filaments of *Cercospora longipes* in the centre. Slightly magnified.

Fig. 18. A spot with perithecia of the second spore-form The brown ring is much reduced in thickness from the increase of the dried-up area in the centre. Slightly magnified.

Fig. 19. A cluster of filaments of *Cercospora longipes* with spores which have fallen from their tips × 260.

Fig. 20. Perithecia of the second spore-form of "brown leaf-spot" × 260.

Fig. 21. A hair from one of the perithecia × 500.

Fig. 22. Upper surface of leaf with perithecia of *Leptosphæria Sacchari*. Slightly magnified.

Fig. 23. Spores found in the early stages of "ring spot" disease and stated by van Breda de Haan to originate the disease.

Fig. 24. Two asci with paraphyses × 500.

Fig. 25. Ascospore of *Leptosphæria Sacchari* × 940.

Fig. 26. Sugar-cane stem bearing the *Melanconium* form of *Trichosphæria Sacchari*. Natural size.

Fig. 27. Sugar-cane stem attacked by *Diplodia cacaoicola* × 2

Fig. 28. Stroma of *Diplodia cacaoicola* in section, showing the pycnidia buried in the dark mass of the stroma × 92.

Fig. 29. Portion of a pycnidium showing the outer thick-walled and inner thin-walled coats. From the latter, filaments bearing spores and paraphyses arise × 260.

Fig. 30. Group of spores of *Diplodia cacaoicola* × 500.

Fig. 31. Sugar-cane stem bearing *Cytospora Sacchari* × 2.

Fig. 32. Stromata of *Cytospora Sacchari* magnified about 20 dia.

Fig. 33. Stroma of *Cytospora Sacchari* in section showing its projection beyond the surface of the cane, and the contained pycnidia cut across in various directions × 85.

Fig. 34. Portion of the pycnidia showing the thick-walled inner coat, from the latter of which crowded, branched filaments bearing spores at their tips arise × 490.

Fig. 35. Two branched spore-bearing filaments from the inner lining of a pycnidium × 490.

Fig. 36. Spores of *Cytospora Sacchari* × 580.

Fig. 37. Section of a cane diseased with "pine-apple" disease. The dark cavities are filled with black powder and fibres. Natural size.

Fig. 38. Microspore-bed of *Thielaviopsis ethaceticus*, formed under the rind which is raised and ruptured by the excessive spore-production. Natural size.

Fig. 39. Microconidial chains partially expelled from the spore-bearing hypha. Drawn from a fixed and stained specimen showing that the conidia are formed some distance within the tubes × 500.

Fig. 40. Large greenish brown endoconidia or macroconidia. From a fixed and stained specimen × 500.

Fig. 41. Macroconidia formed within the spore-bearing hypha but in living specimens appearing to be budded off basipetally × 500.

Fig. 42. Various forms of dark-coloured endoconidia × 500.

Fig. 43. Hypha commencing to extrude microconidia × 260.

Fig. 44. Colourless microconidia, showing the occasional formation of a spherical spore in the chain × 260.

Fig. 45. Germination of microconidia of *Thielaviopsis ethaceticus* × 260.

Fig. 46. Germination of a dark endoconidium × 260.

Fig. 47 Endoconidia of *Sphæronæma adiposum* showing a verticillate arrangement of the spore-bearing hypha. This condition is not uncommon × 500.

Fig. 48. Hyaline endoconidia resembling the microconidia of *Thielaviopsis ethaceticus* × 500.

Figs. 49 & 50. Various forms of the warty brown endoconidia × 500.

Fig. 51. Endoconidium just expelled, showing the remains of the outer layer of the wall adhering to the tips of the warts. Underneath a second spore is partially extruded and the transparent thick wall is visible × 500.

Fig. 52. Formation of first endoconidium. *a*. Apex of tube swollen. *b*. Apex ruptured and wall carried out on the spore.

Fig. 53. Apex of spore-bearing filament × 940.

Fig. 54. Culture obtained from a single spore three days after germination, grown in a hanging drop. *a*. endoconidial branches near the edge of the drop.

Fig. 55. Portion of the neck of a pycnidium of *Sphæronæma adiposum* showing the fringe of filaments round the mouth × 560.

Fig. 56. Portion of the wall of an immature pycnidium showing endoconidia arising from the filaments of the wall × 260.

Fig. 57. Spores from the pycnidia of *Sphæronæma adiposum* × 500.

Fig. 58. Very young stage in the formation of the pycnidial wall showing hyphæ branching and anastomosing × 260.

Fig. 59. Cut end of a set of sugar-cane attacked by *Sphæronæma adiposum*. Natural size.

Figs. 60 & 61. Pycnidia of *Sphæronæma adiposum*. Fig. 60 × 2 fig. 61 × about 8.

Fig. 62. Portion of a filament of the "sooty mould" of sugar-cane showing 2-celled articulations.

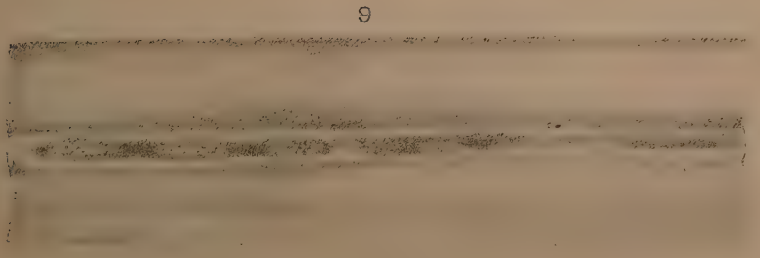
Fig. 63. *Coniothecium*-form of the same fungus × 560.

Fig. 64. *Trisporium*-form of the same × 560.

Fig. 65. Pycnidia of the same × 85.

Fig. 66. Pycnidia showing fringed mouth and spores collected at the apex × 260.

PLATE III.



Colletotrichum falcatum Went.

PLATE IV.

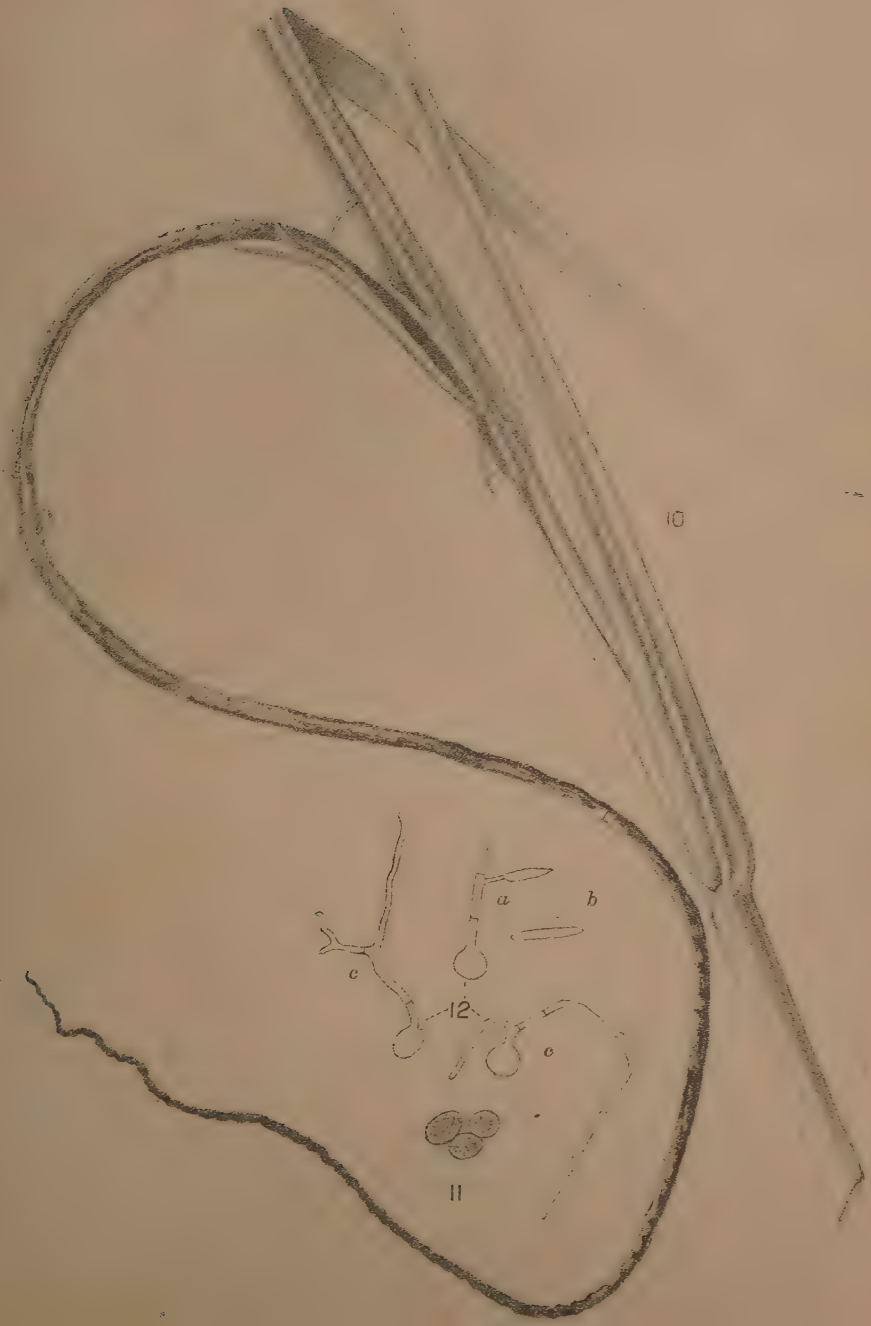
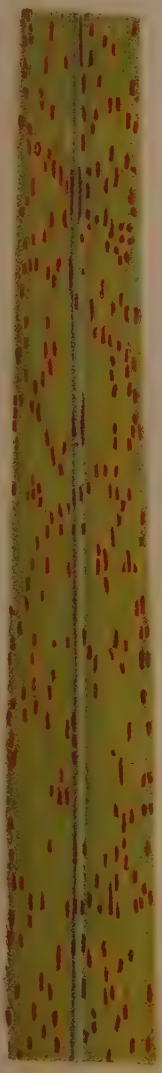


PLATE V.



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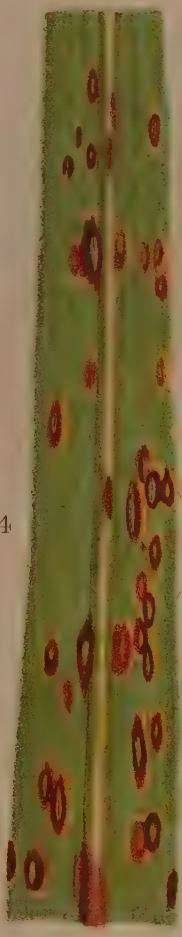

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H.HORMUSJI DEBOO pinx.

West, Newman chromo.

PLATE VI.

Cercospora longipes Butl. and Leptosphæria Sacchari Br. d. H.

PLATE VII.

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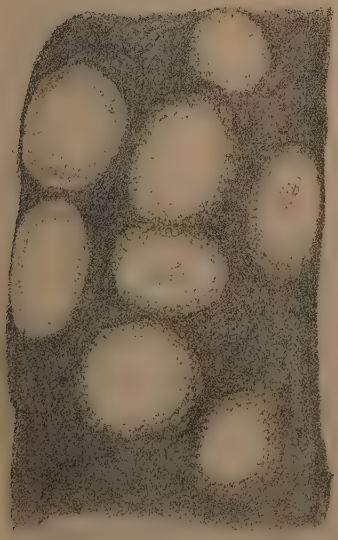

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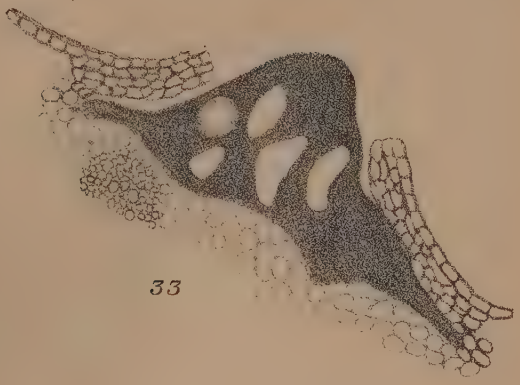
Melanconium Sacchari Massee and Diplodia cacaoicola P. Henn.

PLATE VIII.

31



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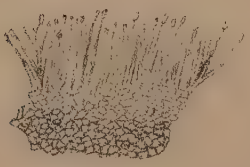

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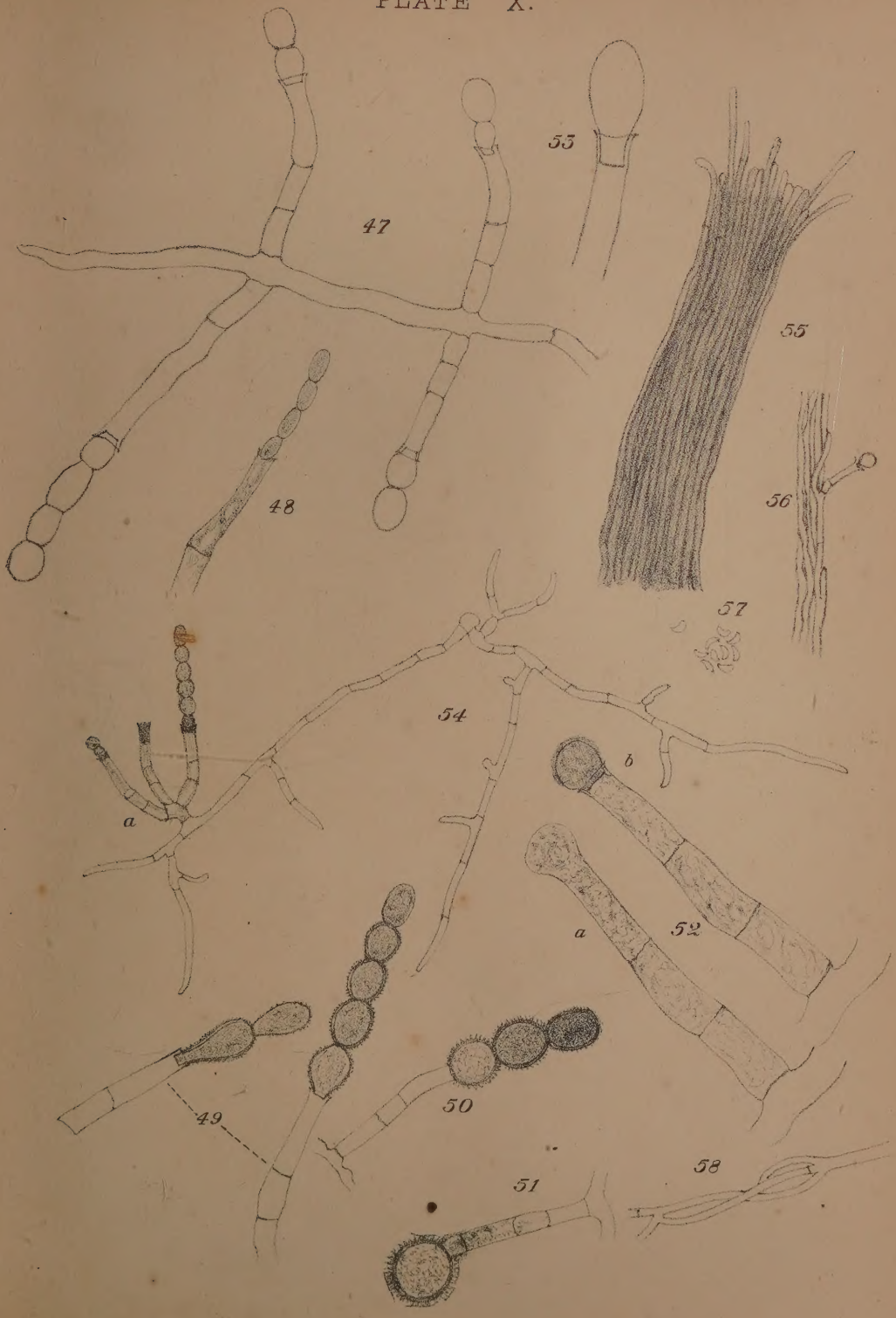
Cytospora Sacchari Butl.

PLATE IX.

Thielaviopsis ethaceticus Went.

PLATE X.



Sphæronæma adiposum Butl.

PLATE XI.

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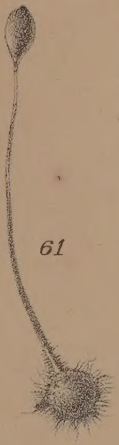

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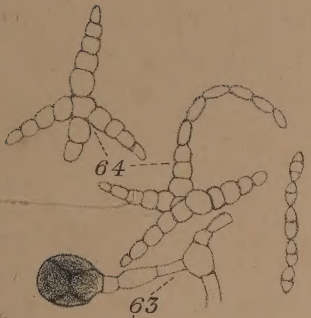

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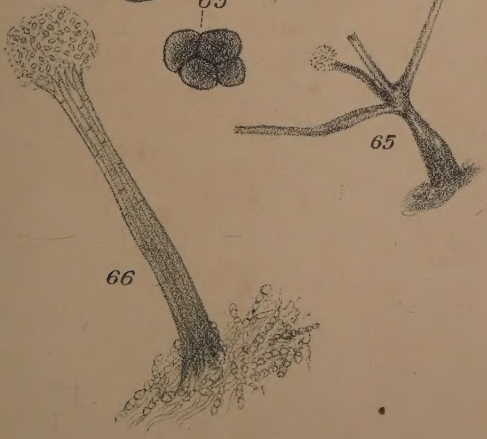

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Sphæronœma adiposum Butl. and Capnodium sp.